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RESEARCH MEMORANDUM

EXPERIMENTAL RESULTS ON WING LOADS DUE TO BLASTS

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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EXPERIMENTAL RESULTS ON WING LOADS DUE TO BLASTS

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SUMMARY

Recent data obtained in the investigation of the loads caused by blast-induced gusts are presented. These data indicate that, when the gusts cause angle-of-attack changes to a point well beyond the stall angle, a load peak travels along the chord which is caused by a vortex formed by the diffraction of the blast wave around the airfoil. When the angle caused by the gust is below the stall angle of the airfoil, it appears that the loading may be calculated by existing unsteady-lift theory for a wide range of the blast position with respect to the wing.

INTRODUCTION

This paper is concerned primarily with some recent information on the traveling-load peak which was found to occur when an intense blast-induced gust increases the angle of attack of the wing to a point well above the steady-flow stall angle (refs. 1 and 2). In addition, some data will be presented for the conditions where weak blast waves strike from directions normal to the wing surface and nearly parallel to the wing span, producing angle-of-attack changes to angles less than the stall angle.

SYMBOLS

Δp_R	resultant pressure, measured from conditions existing prior to blast-wave arrival, lb/sq in.
q	dynamic pressure, lb/sq in.
τ	airstream movement, or aerodynamic time, chords
α	angle of attack, deg

DISCUSSION

Figure 1 is presented as a review of the information previously available on the traveling-load peak. Shown are three sets of load distributions plotted as load coefficient $\Delta p_R/q$ against percent wing chord. These distributions are for three successive times after blast-wave arrival as represented by the values of 0.53, 1.24, and 2.31 chords of travel of the model. The dashed lines with the points represent the model flight data, whereas the solid lines were calculated by simple potential-flow theory ignoring stall and unsteady-lift effects. Two unusual features are apparent in the model flight data. The first is that a loading peak was found that traveled rearward as time passed, and the second is that this peak showed a larger load than the potential-flow calculations which would normally be considered an upper limit to the loading.

The traveling-load peak was believed to result from a vortex that had been formed when the blast wave diffracted around the leading edge of the airfoil and subsequently had been pushed rearward over the upper surface by the steady airflow over the wing. However, no direct evidence was available to substantiate this premise. Accordingly, an experimental investigation was undertaken in the laboratory to visualize the traveling vortices by means of schlieren techniques and to determine how the vortices would move along the chord. The manner in which this was accomplished is shown schematically in figure 2. At the right, an airfoil having one-twentieth the chord of the wing of the model used in the free-flight tests was placed in the airstream issuing from the slot in the flat surface. The airfoil was struck by the blast wave from the actual explosion at the left. The airstream velocity and the gust velocity induced by the blast wave were set at the values obtained for the free-flying model, but the duration of the blast wave was one-twentieth of that to which the free-flying model was subjected in order to account for the reduction in the chord length of the airfoil.

A series of tests was made with the schlieren apparatus adjusted to take photographs of the airfoil and flow at various time intervals after the blast wave struck. A sequence of three photographs, with the airfoil oriented the same as shown in figure 2, is given in figure 3. The picture at the left, which was taken shortly after the blast-wave front passed, shows that vortices have actually been formed by the diffraction of the blast wave around the airfoil and that the one formed at the leading edge has moved slightly back along the chord. The second and third pictures, taken at later times, show that this vortex has moved still farther back along the chord and successively become less distinct and more spread out. The reduction in distinctness is an indication of loss of intensity and conforms to the results from the flight tests shown in figure 1 where the loading peak reduces and spreads out as it moves along the chord.

In reference 1, it was found that the load peak traveled along the chord at a velocity slower than that of the airstream. This is illustrated in figure 1 by the fact that the load peak is still on the airfoil in the third load distribution shown although the airstream has moved more than two chords since the blast wave struck. The schlieren photographs of figure 3 also show the same thing for the vortex. For example, in the middle photograph in figure 3, the vortex which was formed at the leading edge is seen to be only about a third of the way along the chord although the airstream has moved more than 0.9 of a chord. Note that the vortex formed at the trailing edge appears to move at airstream velocity, for it is nearly 1 chord away from the airfoil. The movement of the load peak and the vortex are compared in figure 4. The positions of each along their respective airfoils are shown in terms of percent chord plotted against the chord-length movement of the airstream across the two airfoils. The circles represent the load peak and the squares, the vortex. It is obvious that, despite the twenty-to-one difference in scale, the movement of the load peak and the vortex is the same function of chord-length travel of the airstream. The average velocity of travel of the load peak and vortex appears to be about one-third stream velocity since, in the time they take to pass over the airfoil, the airstream has moved nearly 3 chords.

Recent experimental results are now considered from another phase of the investigation, that of determining the loadings when a weak blast-induced gust strikes a wing and causes an angle change less than the stall angle. Earlier unpublished results have indicated that when a weak blast wave strikes normal to the wing, the loading can be calculated by using existing unsteady-lift theory. Questions have arisen as to whether this procedure would apply if the blast wave struck from a direction well to the side, say at an angle of 20° to 30° to the wing surface. Figure 5 presents the load distribution along the wing chord from one test for such a blast direction together with the results previously mentioned for the blast wave striking normal to the wing. Both represent the load distribution existing at the same very short time after the blast waves struck. Again, the data are plotted as load coefficient $\Delta p_R/q$ as a function of percent of wing chord. The circles are the experimental points associated with the orientation at the right where the blast wave strikes normal to the wing, and the squares are the results obtained when the model rolled as shown so that the blast wave struck at an angle of about 28° to the wing surface. The blast wave and the induced gust velocities were the same for each condition. In making the unsteady-lift calculations, the full gust velocity imposed by the blast wave was used in determining the distribution shown by the solid line for the condition where the blast wave struck normal to the wing. For the rolled condition, however, a simple resolution of vectors was used to determine the component of the gust velocity which acted normal to the wing, and the result of that unsteady-lift calculation is plotted as the dashed line. Both load-distribution calculations are seen to agree well with the experimental data along most of the chord. Near the leading edge, the circle representing the flight result for the blast normal to the wing is somewhat lower than the potential-flow calculation, as often happens, but the square representing the rolled condition is well above its corresponding calculated value. The flow phenomena which caused this are not understood, and, unfortunately, the pressure cell at the 12-percent-chord station did not operate on this flight so it could not be determined if the effect was confined only to the leading edge. The square at the 28-percent-chord station is also high, and again it is not known whether it represents some carryover from the condition found at the leading edge or if its position reflects instrument malfunction. It appears, however, that by a simple resolution of the gust velocity vectors, the loading over the major portion of the chord can be calculated over a wide range of blast incidence angles.

SUMMARY OF RESULTS

Recent data obtained in the investigation of the loads produced by blast-induced gusts have shown that:

1. When the angle-of-attack change caused by the gust is much greater than the stall angle of the airfoil, the load peak traveling along the chord is caused by a vortex formed by the diffraction of the blast wave around the leading edge and its movement is a function of aerodynamic time or chord-length travel.

2. For weak blast waves causing small angle-of-attack changes, it appears that the chord loading may be calculated by existing unsteady-lift theory for a wide range of the blast position with respect to the wing by making a simple resolution of the gust velocity vector to a plane normal to the wing.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 5, 1957.

REFERENCES

1. Pierce, Harold B., and Reisert, Thomas D.: Initial Experimental Investigation of the Aerodynamic Load on the Wing of a Model Caused by a Blast-Induced Gust That Increases the Angle of Attack Into the Stall Region. NACA RM L55H22b, 1955.

2. Pierce, Harold B., and Spahl, Raymond J.: Experimental Investigation To Determine the Loads on a Horizontal Tail of a Model Caused by a Blast-Induced Gust. NACA RM L57A28a, 1957.

EXPERIMENTAL AND CALCULATED LOAD DISTRIBUTIONS

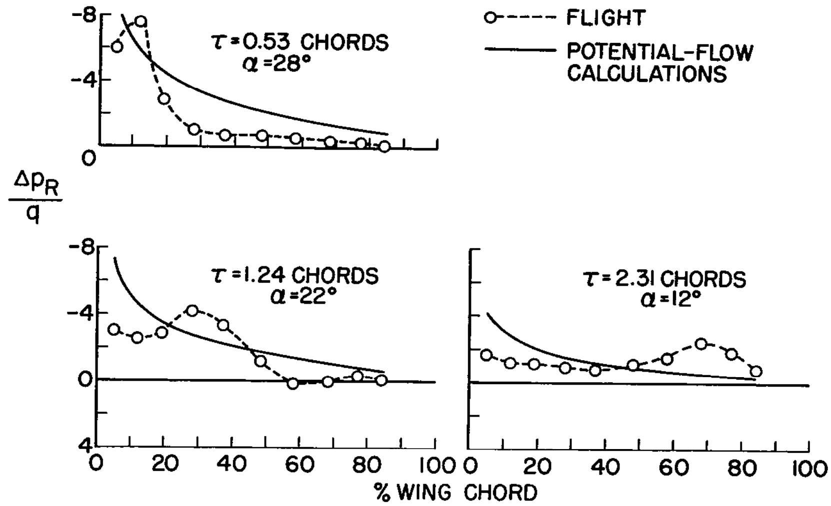


Figure 1

ARRANGEMENT FOR VORTEX-FLOW STUDY

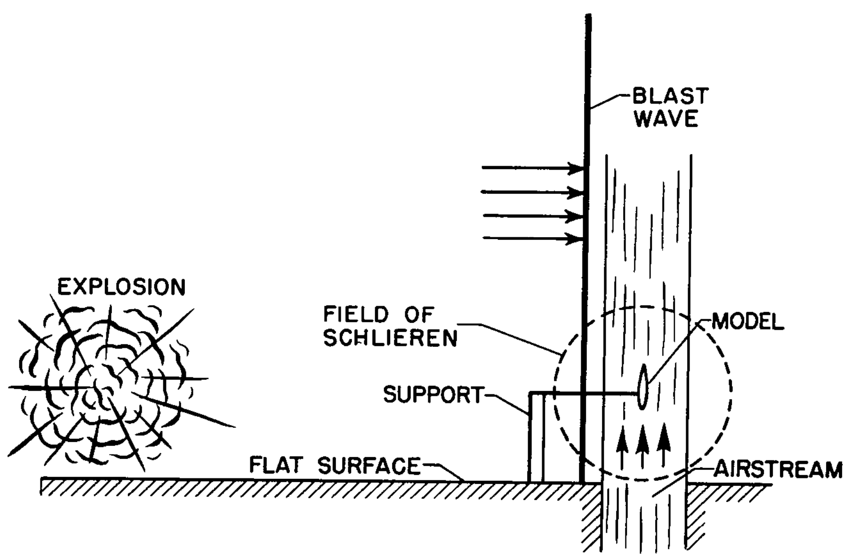
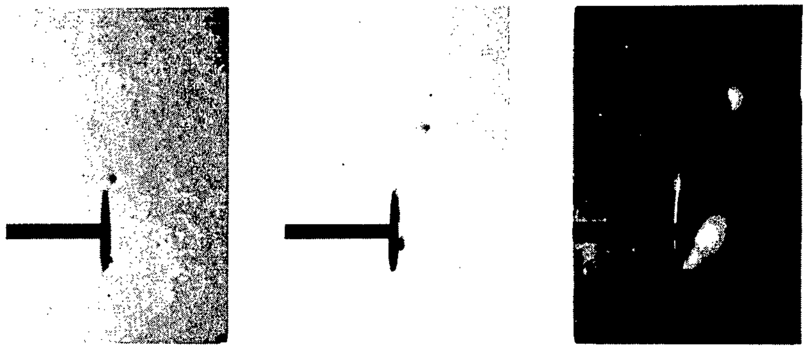


Figure 2

VORTICES FROM BLAST-WAVE DIFFRACTION



τ=0.28 CHORDS τ=0.93 CHORDS τ=1.31 CHORDS

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Figure 3

LOAD-PEAK AND VORTEX TRAVEL ALONG CHORD

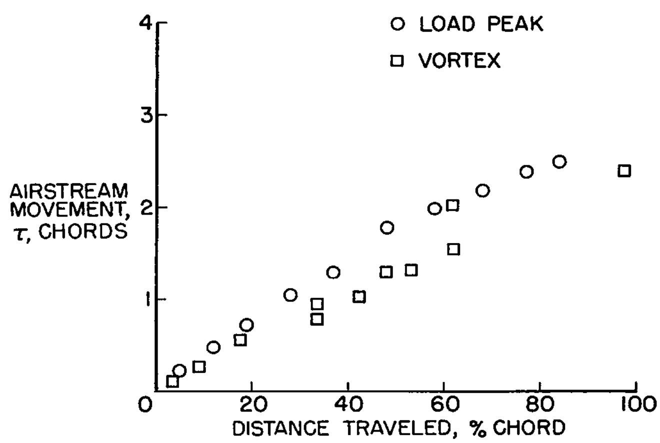

Figure 4

EFFECT OF BLAST - GUST DIRECTION ON LOAD DISTRIBUTION

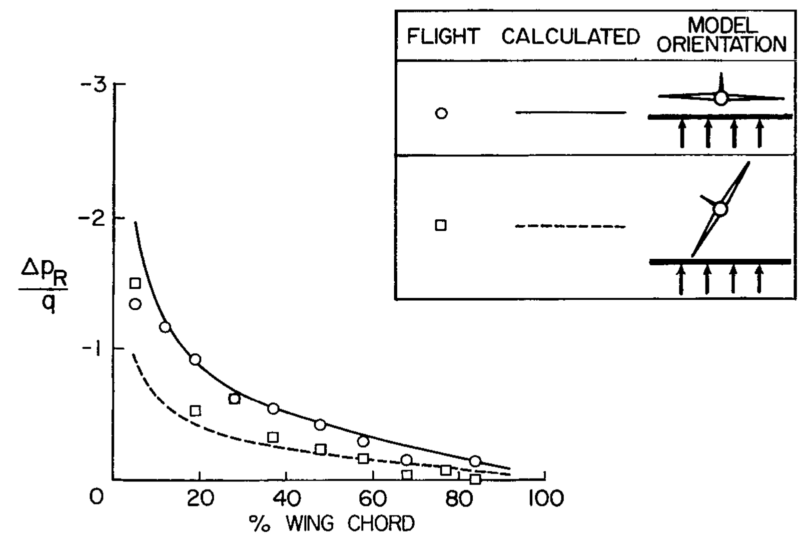

Figure 5

NACA - Langley Field, Va.

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